Jour. Agric. Res. China (中華農業研究) 39(2) : 121~132 (1990)

Mass Production of Phytoseiids :

I. Evaluation on Eight Host Plants for the Mass-rearing of *Tetranychus urticae* Koch and *T. kanzawai* Kishida (Acarina: Tetranychidae)[1]

Wen-Tai Lee, Chyi-Chen Ho and Kang-Chen Lo[2]

Abstracts : Ten crops were evaluated for mass-production of *Tetranychus urticae* Koch and *T. kanzawai* Kishida. Considering the cost of seeds, growth vigor of host plants, and reproduction rate of the spider mites, a soybean native variety, Chin-pe Tou, was the best. The rice seedling-nursery box (60×30×3cm) was chosen to maximize a continuous canopy produced under the least space with the lowest cost. The leaf weight, leaf area and plant height at various cultivating density were compared, and the density of 900 seedlings per box was considered the most economical. This method is suggested as the best method for mass-propagating spider mites so far. Information on the control of the various soybean pests was also given.

Introduction

Biological control of spider mites has been one of the major interest of acarologists in recent years. Among the various natural enemies of spider mites, the predaceous phytoseiids attracted the most attention. Phytoseiids were reported to be the predator of spider mites as early as in 1912 (Quale, 1912). Yet, their applicability was not studied until 1950's. Form then on, many authors studied the production and application of phytoseiids to control spider mites (Kamburov, 1966; McMurtry and Scriven, 1965, 1966 b, 1975; and Ristich 1956). However, these efforts to produce phytoseiids were primarily for small scale releases. The large scale releases were initiated only in the last 10 years (Fournier et al., 1985; Hendrickson, 1980; Hoy et al., 1982; and Storozhrov and Kaznacheeva, 1980).

Artifical diet has been studied for raising tetranychids (Fritzsche, 1960; Rodriguez and Davis, 1971; Storms and Noordink, 1970) and phytoseiids (Kennett and Hamai, 1980; McMurtry and Scriven, 1962, 1966a; Ochieng et al., 1987; Shehata and Weismann, 1972). None of these was proven to be promising for mass production programs. Therefore, the most effective way of mass-producing phytoseiids is utilizing spider

---

1. Contribution No. 1511 from Taiwan Agrcultural Research Institute (TARI), Wufeng, Taichung, Taiwan, Republic of China.

2. Assistant Entomologist, Entomologist, and Senior Entomologist, respectively. Department of Applied Zoology, TARI.

mites reared on host plants. Various host plants have been used to raise spider mites. The propagation of spider mites varied among host plants (Finney, 1953; Gerson and Aronowitz, 1980) and among varieties of the same host plant (Ashihare et al., 1986). The authors studied sweet potato, corn, water convolvulus, Mexican ageratum, clover and a few other crops in preliminary tests. Clover grew poorly under the hot climate of Taiwan and its leaf was too small to handle. The other crops were not as good as leguminous crops. This study compared ten leguminous crops and presents an economical and efficient method to grow a thick canopy to raise spider mites.

Materials and Methods

Crops characterized by their fast growing were selected for this study. After preliminary test, 10 crops of Leguminosae were chosen for comparing their suitability in raising spider mites, *Tetranychus kanzawai* Kishida and *T. urticae* Koch. These leguminous crops are:

Soybean	*Glycine max* L.
Chin-pe Tou	*Glycine max* L.
Hay Tou	*Glycine max* L.
Dutch case-knife bean	*Phaseolus coccineus* L.
Limabean	*P. limensis* Macf.
Snapbean	*P. vulgaris* L.
Pea	*Pisum sativum* L.
Sesbania	*Sesbania sesban* Merr.
Mungbean	*Vigna angularis* (Willd.) Ohwi et Ohashi
Adzukibean	*V. radiata* (L.) R. Wilcz.

The developing stages of the test crops were described following the system of Fehr et al. (1971), using V1, V2, and V3 to record the complete unroll of the primary leaf, the first trifoliate leaf, and the second trifoliate leaf, respectively.

Cost of Seeds

The averaged prices of seeds of the test crops were obtained through surveys of 3 stores in central Taiwan. As the sizes of seeds varied greatly among crops, this price was not the true cost of seeds. Therefore, a cost index (seeds per NT dollar) was calculated following the formula:

Cost index=1000 (gm)/seed wt. (gm)/price (NT/kg seeds.)

The seed weight was averaged from 10 measures of 100 seeds.

The Propagation rate of Spider Mites on the Host Plants.

A. Test 1.

Six, crops including soybean, Chin-pe Tou, Dutch case-knife bean, limabean, snapbean, and pea, were planted in October 1985. These crops were grown in 10×10cm pots. Each pot contained 2 seedlings of the same crop, and 5 replicates were made. These pots were kept in screen house. Ten adult females of *T. kanzawai* or *T. urticae* were introduced onto each plant at the V1 stage. The number of spider mites on each plant was counted 14 days after the introductions. The temperature ranged 19.5—31.3C and relative humidity ranged 65—100% during the experimental period. Crops selected from this test were compared with other crops in test 2.

B. Test 2.

Methods used in test 1 were adopted in this test, except only *T. urticae* was intro duced, and the test was conducted in a growth chamber under 28C, 70—90% R. H., and 14 : 10(L : D) photoperiod. Eight crops including soybean, Chin-pe Tou, Hay Tou, limabean, snapbean, sesbania, adzukibean, and mungbean were studied from January to March. 1987.

The Growth Vigro of Host Plants

The test crops were sowed in rice seedling-nursery boxes (60×30×3cm), 45 boxes for each crop, in a screen house. Coarse sand was used as cultivating material. Twenty seedlings were allowed to grow up in each box. The fresh leaf weight and leaf area were measured at V1, V2, and V3 stages. Ten plants were measured each time for each crop with 15 replications. This study was conducted twice, once in summer (July-August, 1987), and repeated in winter (December-January, 1987—1988). Leaf area was measured by a leaf area meter (LI-COR, LI-3000). Leaf weight was measured by a fine balance (Sauter, model 414).

The Cultivating Density of Host Plants in the Rice Seedling-Nursery Box

After selecting a right crop, the proper density to cultivate the crop was tested. Chin-pe Tou, the selected crop, was grown in the rice seedling-nursery box same as the aforementioned test at the densities of 100, 200, 300, 400, 500, 600, 700, 800, and 900 seedlings per box, with 8 replications. Leaf area, leaf weight, and plant height were measured as in the growth vigor test. Twenty plants were sampled randomly each time from each box, and measured individually.

Results

Cost of Seeds

The seeds are sold in the unit of kilogram. Yet the sizes of seeds varied greatly

Table 1. The costs of seeds of the test crops

Crops	Price (N.T.$/kg) (a)	Wt./100 seeds (gm) (b)	Cost index* (Seed/N.T.$)
Soybean	46.7	12.79	167.40
Chin-pe Tou	46.7	6.22	343.99
Hay Tou	46.7	17.54	122.07
Dutch case-knife bean	166.7	43.96	13.65
Limabean	601.3**	166.31	1.00
Snapbean	666.7	13.36	11.23
Pea	166.7	16.96	35.38
Sesbania	60.0	1.79	929.23
Mungbean	33.3	6.04	497.38
Adzukibean	36.7	14.78	184.39

*Cost index=1,000/(b/100)/a
**One NT dollar/seed

among crops. For example, a limabean seed weighted ca. 93 times of a sesbania seed. Hence, the number of seeds purchased per NT dollar was calculated in Table 1 to compare the true cost of seeds. Limabean was most expensive, followed by snapbean, Dutch case-knife bean, pea, Hay Tou, soybean, adzukibean, Chin-pe Tou, and mungbean. Sesbania was the cheapest.

The Propagation rate of Spider Mites on the Host Plnt

The results of Test 1 were shown in Table 2. Among the 6 tested crops, pea was a good food source for *T. urticae*, but was poor for *T. kanzawai*. Limabean and snapbean which were most commonly used by other researchers gave poor results both for *T. urticae* and *T. kanzawai*. Chin-pe Tou, Dutch case-knife bean, and soybean gave high performance for the growth of both spider mite species. Production of the spider mites by these 3 crops were 5 to 10 folds of the other crops. Therefore, these 3 crops were selected and tested again in Test 2. Snapbean was included for its large leaf size and smooth leaf surface.

Table 2. *Tetranychus urtiae* and *T. kanzawai* raised from six crops*

Crops	*T. kanzawai*			*T. urtiae*		
	Egg	Adult + Young	Total *	Egg	Adult + Young	Total *
Chin-pe Tou	2,571	357	2,928a	2,587	313	2,900a
Duth case-knife bean	1,816	786	2,602a	1,109	1,137	2,246ab
Soybean	1,176	1,658	3,134a	1,117	948	2,065ab
Pea	268	272	540b	1,141	384	1,525b
Snapbean	535	104	639b	199	34	233c
Limabean	154	72	226b	126	54	180c

*Mean from 10 plants at the 14th day after the introduction of spider mites. Means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test.

The results of Test 2 were give in Table 3. Among the test crops sesbania produced the highest number of *T. urticae*. Soybean and Chin-pe Tou produced high number of *T. urticae* and showed conisstently good results. Dutch case-knife bean was the worst for propagating spider mites, while the others were in the middle.

Table 3. *T. urtiae* raised on 8 crops under 28C, 70—90% R. H. in growth chamber

Crops	*T. urtiae*		
	Egg	Adult+Young	Total *
Sesbania	1,478	496	1,974a
Soybean	1,539	390	1,929ab
Chin-pe Tou	1,374	317	1,691abc
Hay Tou	781	464	1,245bc
Mungbean	989	286	1,275bc
Snapbean	911	239	1,129cd
Adzukibean	747	231	978cd
Dutch case-knife bean	254	43	297d

*Mean from 10 plants at the 14th day after the introduction of spider mites. Means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test.

The Growth Vigor of Host Plants

The growth vigor studies were conducted both in summer and winter, because the host plant should be grown year-round. Limabean was discarded early in this study because of its poor performance in the rice seedling-nursery box. Pea was also excluded from the test due to poor and uneven germination.

Under the testing conditions, mungbean stopped growing at V2 stage. Snapbean grew normally in summer, but stopped growing at V2 stage in winter. The other crops grew normally. Hay Tou was out of supply in the winter time, therefore, it was not tested in winter. The results of this study were listed in Table 4 (summer) and Table 5 (witer).

Table 4. Leaf weight (gm/plant) and leaf area (cm²/plant) of 8 crops at 3 developmental stages* cultivated in the rice seedling-nursery box in summer (July-August, 1986)

Crops	Leaf wcight			Leaf Area		
	V1	V2	V3	V1	V2	V3
Soybean	0.267	0.623	1.255	15.289	36.672	69.317
Chin-pe Tou	0.133	0.308	0.601	8.749	20.442	37.034
Hay Tou	0.261	0.683	1.087	14.933	39.341	61.445
Dutch case-knife bean	1.149	2.511	3.121	36.973	79.694	102.412
Snapbean	0.551	1.373	2.391	23.233	50.876	75.224
Sesbania	0.025	0.080	0.135	1.349	4.092	7.333
Mungbean	0.181	0.421	—	8.496	15.099	—
Adzukibean	0.210	0.571	0.652	8.042	25.673	29.024

* V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

Table 5. Leaf weight (gm/plant) and leaf area (cm^2/plant) of 7 crops at 3 developmental stages* cultivated in the rice seedling-nursery box in winter (December-January, 1986—1987).

Crops	Leaf weight			Leaf Area		
	V1	V2	V3	V1	V2	V3
Soybean	0.308	0.554	0.884	16.858	31.941	47.161
Chin-pe Tou	0.187	0.412	0.665	11.052	20.640	36.383
Dutch case-knife bean	1.688	2.943	3.479	61.414	98.425	122.740
Snapbean	0.476	1.331	—	13.254	49.215	—
Sesbania	0.014	0.030	0.053	0.701	1.945	2.618
Mungbean	0.203	0.395	—	8.831	14.854	—
Adzukibean	0.193	0.493	0.606	9.835	21.659	24.280

*V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

The growth period of the test crops in winter took twice as long as in summer. The leaf weight and leaf area of the crops grown in the winter were generally less than those grown in the summer. Dutch case-knife bean and Chin-pe Tou were the exceptions, which grew better in the winter. Generally, the larger seed produced a plant with a greater leaf area and heavier leaf weight, with one exception of adzukibean. Accordingly, no statistic analysis was carried on these data. Instead of, these data and the cost index in Table 1 were calculated for the leaf weight and leaf area produced per NT dollar, and the results were drawn in Figures 1, 2, 3, and 4. Among the

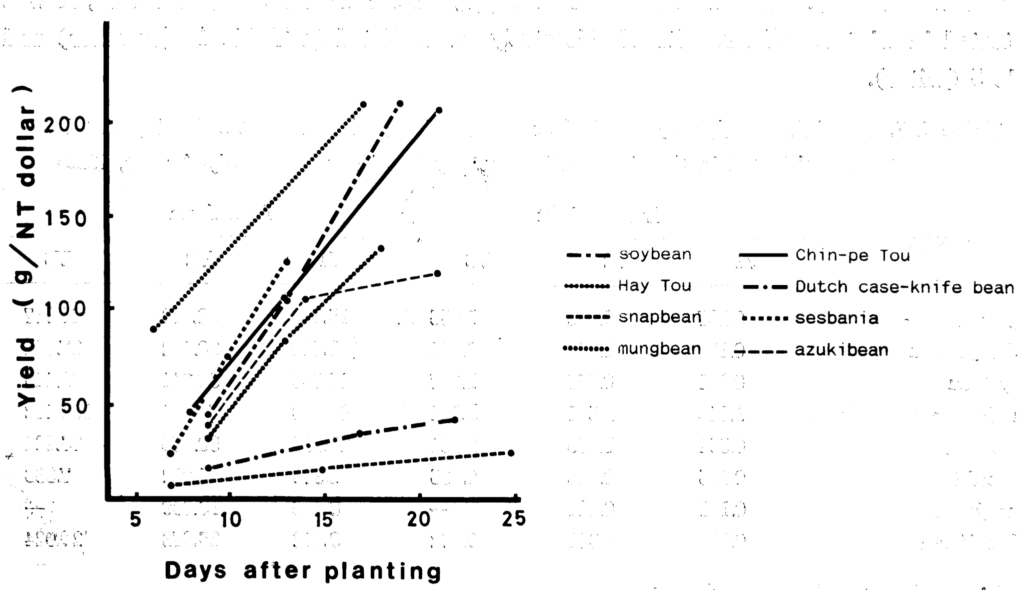

Figure 1. Leaf weight of various crops produced per NT dollar in summer (July –August, 1986)

three test crops, Chin-pe Tou yielded the largest leaf area and the heaviest weight per unit cost both in summer and winter. Mungbean was comparable to Chin-pe Tou for leaf weight but not for leaf area. Soybean grew well in summer but not in winter.

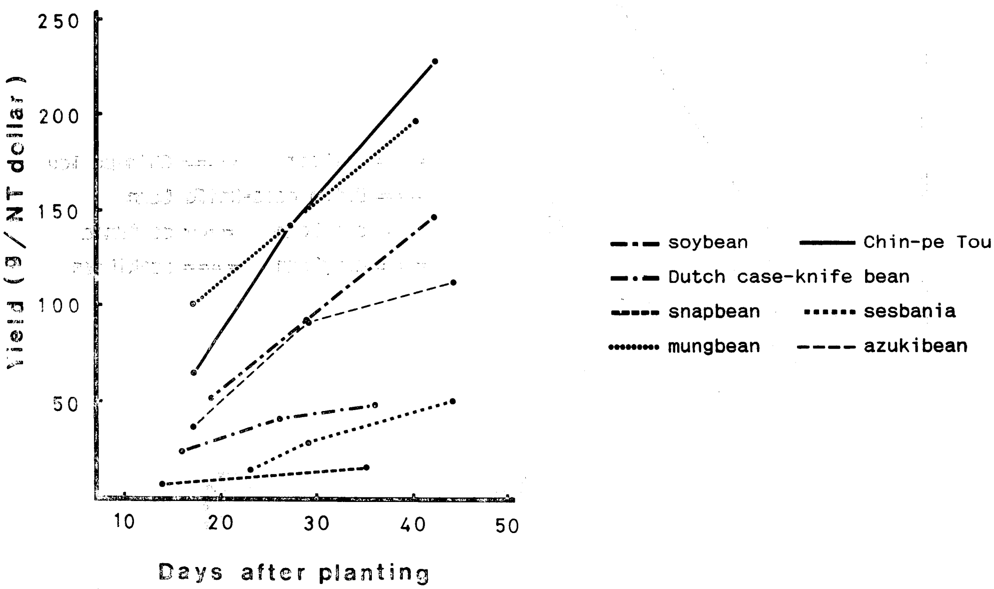

Figure 2. Leaf weight of various crops produced per NT dollar in winter (December-January, 1986—1987)

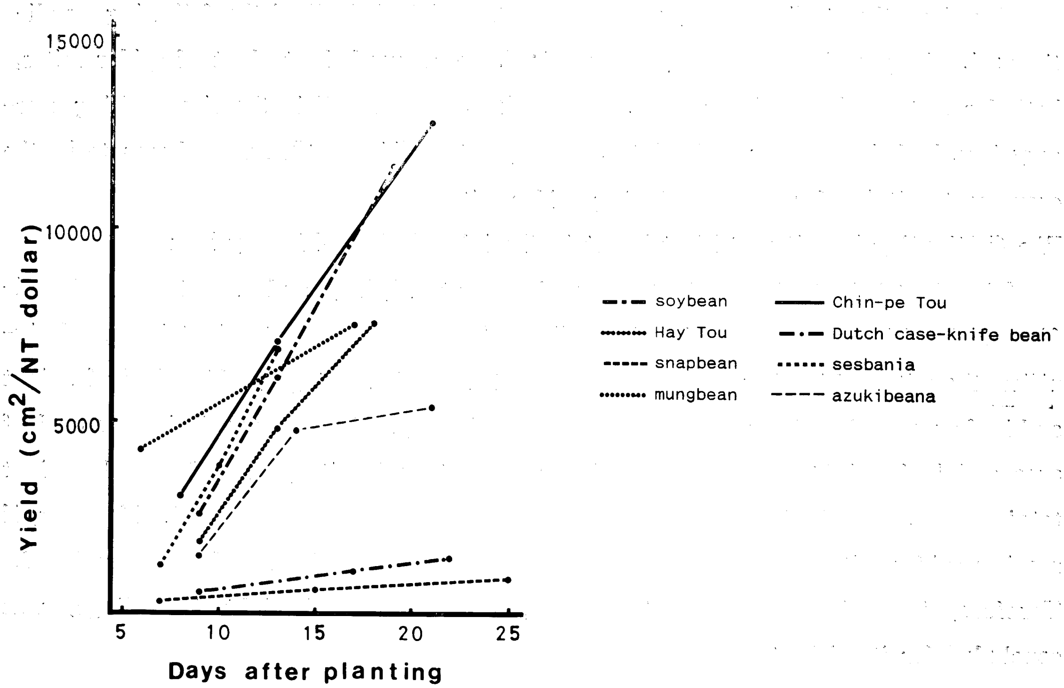

Figure 3. Leaf area of various crops produced per NT dollar in summer (July-August, 1986)

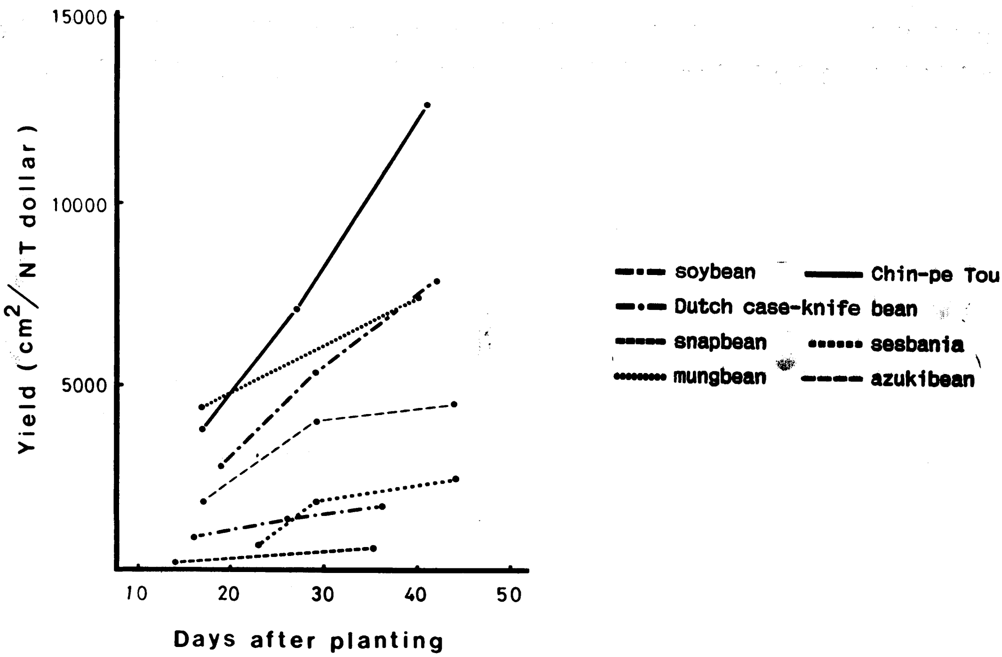

Figure 4. Leaf area of various crops produced per NT dollar in winter (December-January, 1986—1987)

Based on the studies above, only Chin-pe Tou fulfilled all of the following conditions: 1. Cheap and available year-round; 2. Be a good host plant of spider mites, both for *Tetranychus urticae* and *T. kanzawai*; 3. Grown well in the rice seedling nursery box, both in summer and winter. Consequently, Chin-pe Tou was chosen to be the crop most suitable for mass-producing spider mites.

The Cultivating Density of Host Plant in the Rice Seedling-Nursery Box

The plant height, leaf weight and leaf area at V1, V2, and V3 stages under different densities were shown in Figure 5 and Table 6. The plant height increased significantly with cultivating density especially at V2 and V3 stages, while the leaf weight and leaf area produced per plant decreased significantly. Although the difference on leaf area and leaf weight was not large, higher cultivating density produced more luxuriant total canopy. The high-grown plant is easy to be blown down by wind. However, if rearing spider mites in a glass house or a screen house, such hazard can be reduced. Terefore, 900 Chin-pe Tou plants per box, though produced hightest seedlings, was concluded for its richest canoy.

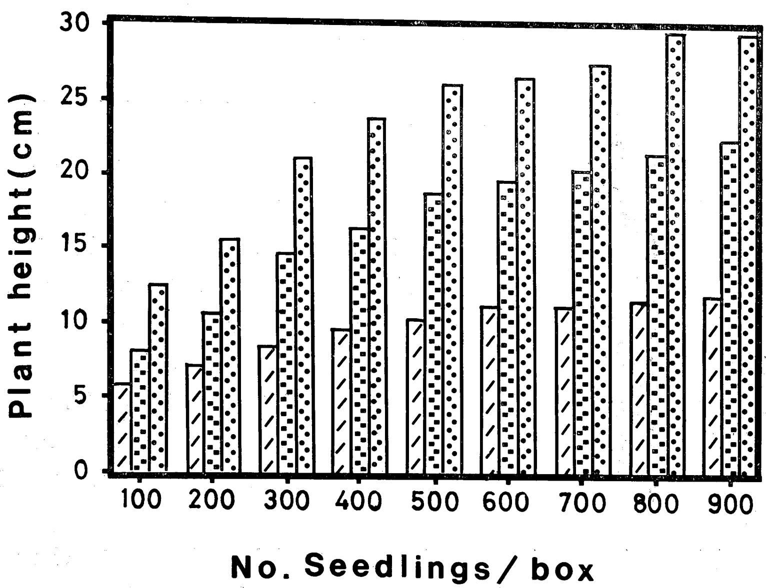

Figure 5. Height of Chin-pe Tou at 3 developing stages under various cultivating densities.

Table 6. Leaf weight (gm/plant) and leaf area (cm^2) of Chin-pe Tou at 3 developing stages* under various cultivating densities.

Density (seedling/box)	Leaf weight			Leaf Area		
	V1	V2	V3	V1	V2	V3
100	16.68	36.55	60.45	1.203	2.681	4.569
200	33.69	74.18	115.40	2.399	5.495	8.670
300	45.35	105.66	177.72	3.366	8.042	13.235
400	63.87	139.68	231.36	4.894	10.823	16.847
500	70.83	173.15	261.65	5.337	12.938	20.411
600	84.14	201.90	322.98	6.459	15.247	23.509
700	91.73	238.21	359.11	7.276	18.204	27.520
800	103.80	260.32	426.48	8.332	20.214	32.615
900	117.03	298.26	457.56	9.267	22.916	35.442

*V1 : complete unroll of the primary leaf.
V2 : complete unroll of the 1st trifoliate leaf.
V3 : complete unroll of the 2nd trifoliate leaf.

Discussion

The price of seed varied with season and region. A seed with a steady price is usually supplied steadily. Chin-pe Tou is available year-round and its price is quite stable. This a very important advantage for a mass-rearing program and played an important role while the authors made decision on the most suitable host plant.

Ashihara et al. (1986) compared the ovipostion of *T. urticae* on 4 varieties of kidney bean (=snapbean of this study) and 2 varieties of soybean. They concluded that the former is better because kidney bean grew faster and had greater leaf area than soy bean, and spider mites oviposited more eggs on kidney bean. In our studies, soybean grew faster than snapbean both in summer and winter, and both *T. urticae* and *T. kanzawai* had higher reproductive rates when feed on soybean than on snapbean. This may be due to the difference in the variety tested and, especially, the difference in the cultivating method.

Crops for raising spider mites can be cultivated in fields, pots, bag, or shallow pans. Most researches grew crops in fields or pots, and exposed them to spider mites at the later stage of crop development. This had the advantages of labor saving and providing more leaf surface for raising spider mites. However, growing crops in fields or pots has a greater risk to be invaded by other insects and mites, phytophagous or predaceous, which would interfere the mass-production effort (Finney 1953, Scriven and McMurtry 1971).

Scriven and McMurtry (1971) reduced the possibility of the establishment of mite predators and phytophagous insects on the crops by rapid turnover of plants. We found that the rice seedling-nursery box was ideal for cultivating the crops, because: 1. It can sustain the growth of many crops up to V4 stage, which is long enough for rearing phytoseiids. 2. Only a small amount of sand or cultivating material is required because of the shallowness of the box. Consequently, it is not heavy and easy to handle. 3. As there is less vacuity between the boxes, it is space-saving when compared with the round-shaped pot. 4. It is a marketed product, and is, therefore, cheap and readily available.

Scriven and McMurtry (1971) grew 100 plants in a 18×24×2 in (ca 0.28m^2) tray, and produced 1.29g of *Pacificus* (ca. 353,860 individuals of all stages). Storozhkov and Kaznacheeva (1980) reported the production of 174,400 phytosiids per m^2 per season in glass house. The rice seedling-nursery box was measured 0.18m^2. An estimation of over 1,000,000 spider mites or 15,000 phytoseiids of all stages could be reared each time from each box. This was considerably higher than those found in other reoports. This method is, therefore, suggested as the best method for mass-propagating spider mites so far.

There were a few diseases and insect pests attacking Chin-pe Tou during growing periods. These pests were controlled by using chemical and mechanical method. The major pathogens, *Pythium* spp. and *Rizoctonia* spp. were controlled by 1. Dipping seeds in either the 2000x dilution of Etridiazole 35% W. P. or the 1500x dilution of Iprodione 50% W. P. for two hours; or 2. Mixing each kilogram seeds with any of the fungicides below: 2g of Thiram 65% W. P., 4g of Chlorothalonil 75% W. P., or 2g of Etridiazole 35% W. P., Lepidopteran pests, such as Tobaccoo cutworm, leaf roller, and tussock moth, were controlled by 2000x dilution of Methomyl 90% W. P. The best way to control lepidopteran pests was to keep the plants free from the infestation of moths by growing them inside screen house. Aphids could be controlled with the 20000x dilution of Pirimicarb 50% W. P. which showed no negative effect on the growth of spider mites.

Acknowledgements

This research is granted by the Council of Agriculture, Republic of China. Thanks also go to Dr. J. C. Chen, Dr . D. J. Liu, and Dr. B. Y. Lai for their valuable sugestion on this manuscript.

Reference Cited

Ashihara, W., Inoue, K. and Osakabe, M. 1986. A mass rearing method for *Phytoseiulus persimilis* (Acarina: Phytoseiidae). I. Leaf morphology and oviposition of *Tetranychus urticae* (Acar ina: Tetrarnychidae) on the beans and fecundity of *Phytoseiulus persimilis* and three *Tetra nychus* species. Ball. Fruit Tree Res. Stn. Ser. E (Akitsu) 6 : 91-102.

Fehr, W. R., Caviness, C. E., Burmood, D. T. and Pennington, J. S. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11 : 929-931.

Finney, G. L. 1953. A technique for mass-culture of the sixspotted mite. J. Econ. Entomol. 46 : 712-713.

Fournier, D., Millot, P. and Pralavorio, M. 1985. Rearing and mass production of the predatory mite *Phytoseiulus persimilis*. Entomol. Exp. Appl. 38 : 97-100.

Fritzsche, R. 1960. Morphologische, biologische, und physiologische variabilita und ihre bedeutung fu epidemilogie und bekmpfung von *Tetranychus urticae* Koch. Biol. Zentralb 79 : 521-576.

Gerson, U. and A. Aronowitz. 1980. Feeding of the carmıne spider mite on seven host plant species. Entomol. Exp. Appl. 28 : 109-115.

Hendrickson, R. M., Jr. 1980. Continuous production of predaceous mites in the greenhouse. J. New York Entomol. Soc. 88 : 252-256.

Hoy, M. A., Barnett, W. W., Reil, W. O., Castro, D., Cahn, D., Hendricks, L. C., Coviello, R. and Bentley, W. J. 1982. Large-scale releases of pesticide-resistant spider mite predators. Calif. Agric. 36 : 8-10.

Kamburov, S. S. 1966. Methods of rearing and transporting predaceous mites. J. Econ. Entomol. 59 : 875-877.

Kennett, C. E. and Hamai, J. 1980. Oviposition and development in predacious mites fed with artificial and natural diets (Acari: Phytoseiidae). Entomol. Exp. Appl. 28 : 116-122.

McMurtry, J. A. and Scriven, G. T. 1962. The use of agar media in tranlporting and rearing phytoseiid mites. J. Econ. Entomol. 55 : 412-414.

McMurtry, J. A. and Scriven, G. T. 1965. Insectary production of phytoseiid mites. J. Econ. Entomol. 58 : 282-284.

McMutry, J. A. and Scriven, G. T. 1966a. Effects of artificial foods on reproduction and development of four species of phytoseiid mites. Ann. Entomol. Soc. Am. 59 : 267-269.

McMutry, J. A. and Scriven, G. T. 1966b. The influence of pollen and prey density on the number of prey by *Amblyseius hibisci* (Acarina: Phytoseiidae). Ann. Entomol. Soc. Am. 59 : 147-149.

McMutry, J. A. and Scriven, G. T. 1975. Population increase of *Phytoseiulus persimilis* on different insectary feeding programs. J. Econ. Entomol. 68 : 319-321.

Ochieng, R. S., Oloo, G. W. and Amboga, E. O. 1987. An artificial diet for rearing the phytoseiid mite, *Amblyseius take* Pritchard and Baker. Exp. Appl. Acarol. 3 : 169-173.

Quayle, H. J. 1912. Red spiders and mites of citrus trees. Calif. Agric. Exp. Sta. Bull. 234 ; 483-530.

Ristich, S. S. 1956. Mass rearing and testing techniques for *Tyyphlodromus fallacis* (Gar.) J. Econ. Entomol. 49 : 476-479.

Rodriguez, J. G. and Davis, D. L. 1971. Influence of dietary improvement on oviposition and egg viability of the mite *Tetranychus urticae.* J. Insect Physiol. 17 : 1393-1399.

Scriven, G. T. and McMurtry, J. A. 1971. Quantitative production and processing of tetranychid mites for large-scale testing or predator production. J. Econ. Entomol. 64 ; 1255-1257.

Shehata, K. K. and Weismann, L. 1972. Rearing the predaceous mite *Phytoseiulus persimilis* Anthias-Henriot on artificial diet (Acarina: Phytoseiidae). Biologia Bratislava 27 : 609-615.

Storms, J. J. H. and Noordink, J. Ph. W. 1970. Nutritional requirements of the twospotted spider mite, *Tetranychus urticae* (Acarina: Tetranychidae). 7 Eur Mite Symp. Pol. Akad. 29-39.

Storozhkov, Yu. V. and Kaznacheeva, V. P. 1980. Rearing of *Phytoseiulus persimilis* in hydroponic greenhouses. Zashchita Rastenii 1980 ; 30.

捕植蟎之大量繁殖

I 葉蟎飼育植物之選擇[1]

李文台 何琦琛 羅幹成[2]

摘　　要

以水稻育苗箱爲栽種器材，測試比較種子購買成本，植物生長速率及葉蟎繁殖速率等三項因素，自10種豆科植物中選出本地土生品系之青皮豆爲大量繁殖捕植蟎所需之葉蟎飼育用植物。爾後測量葉面積、葉重及株高三項性狀，選擇每育苗箱種植 900株青皮豆爲最佳種植密度。如此，可在最小之空間上以最低之生產成本，全年持續不斷地生產最大量之葉蟎飼育植物，做爲大量繁殖捕植蟎之基礎。

1.臺灣省農業試驗所　研究報告第 1511 號。

2.本所應用動物系助理研究員、副研究員、研究員兼系主任。臺灣省　臺中縣　霧峰鄉。